Tracking the Sun II

The Installed Cost of Photovoltaics in the U.S. from 1998-2008

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- Report Summary -

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Project Overview

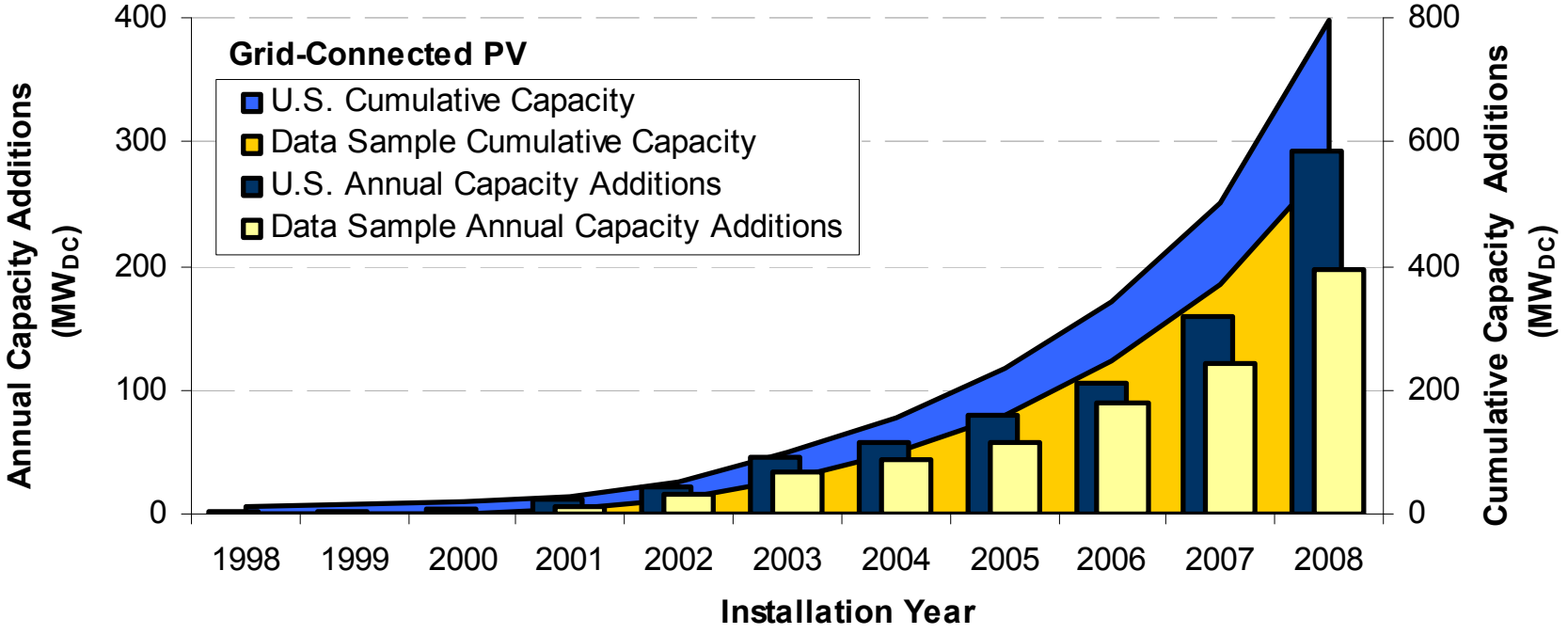
Objective: Using project-level data, evaluate trends in the installed cost of grid-connected PV systems throughout the U.S. to answer the following:

- How have installed PV costs changed over time?
- To what extent are these trends associated with module vs. non-module costs?
- To what extent do installed costs and component-level cost vary by system size?
- To what extent have costs varied by country, state, and incentive program?
- How do costs differ between applications and technologies?
  - residential vs. commercial vs. public sector vs. non-profit
  - residential new construction vs. residential retrofit
  - building-integrated vs. rack-mounted
  - thin-film vs. crystalline silicon
  - tracking vs. fixed-axis
- How have PV incentives changed over time, and how do they vary across states?
- How have net installed costs for residential and commercial PV changed over time, and how do they vary across states?

Data and Methodology

- Sought project-level cost data from as many PV incentive programs in the U.S. as reasonably feasible, with some focus on larger programs
- Ultimately, data were obtained from 27 solar incentive programs spanning 16 states, with PV system sizes ranging from 100 W_{DC} to 1.6 MW_{DC}
- Primary sample includes roughly **52,000 grid-connected PV systems** installed from 1998-2008, totaling **566 MW**
  - All systems in the primary sample are installed on the electric-customer side of the meter
  - Additional cost data for nine 2+ MW systems, several of which are installed on the utility-side of the meter, were obtained from press releases and other public sources
- Reported costs are those paid by the system owner, before any incentives
- Cost data are expressed in real 2008$, and size data are converted to direct current watts at standard test conditions (denoted as W_{DC} in slides)
- Data were cleaned to only include system costs of $2-30/W, systems where total incentives were <$30/W, and only systems with installed cost, size, and incentive level reported

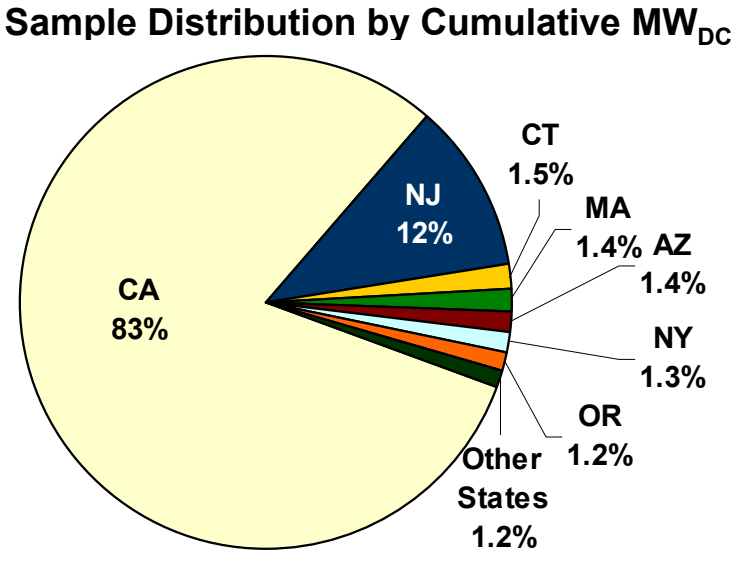
Primary Sample Represents 71% of Grid-Connected PV Installed in U.S. through 2008

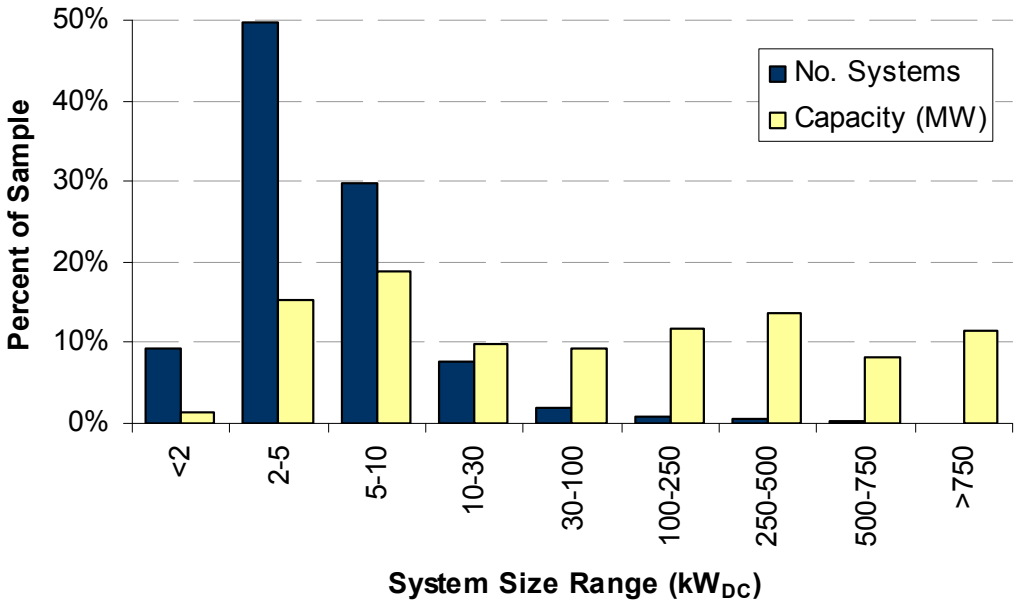


Source for U.S. Capacity Data: Sherwood, L. 2009. U.S. Solar Market Trends 2008. Interstate Renewable Energy Council.

- Estimated $2.1 billion investment in grid-connected, customer-sited PV in the U.S. in 2008; primary data study sample represents $1.5 billion
- Including the additional nine >2 MW_{DC} projects (for which cost data were obtained from press releases and other public sources) in the tally brings the sample to **78%** of cumulative U.S. grid-connected PV capacity through 2008

Summary Information on Dataset: States, System Size, Temporal Distribution





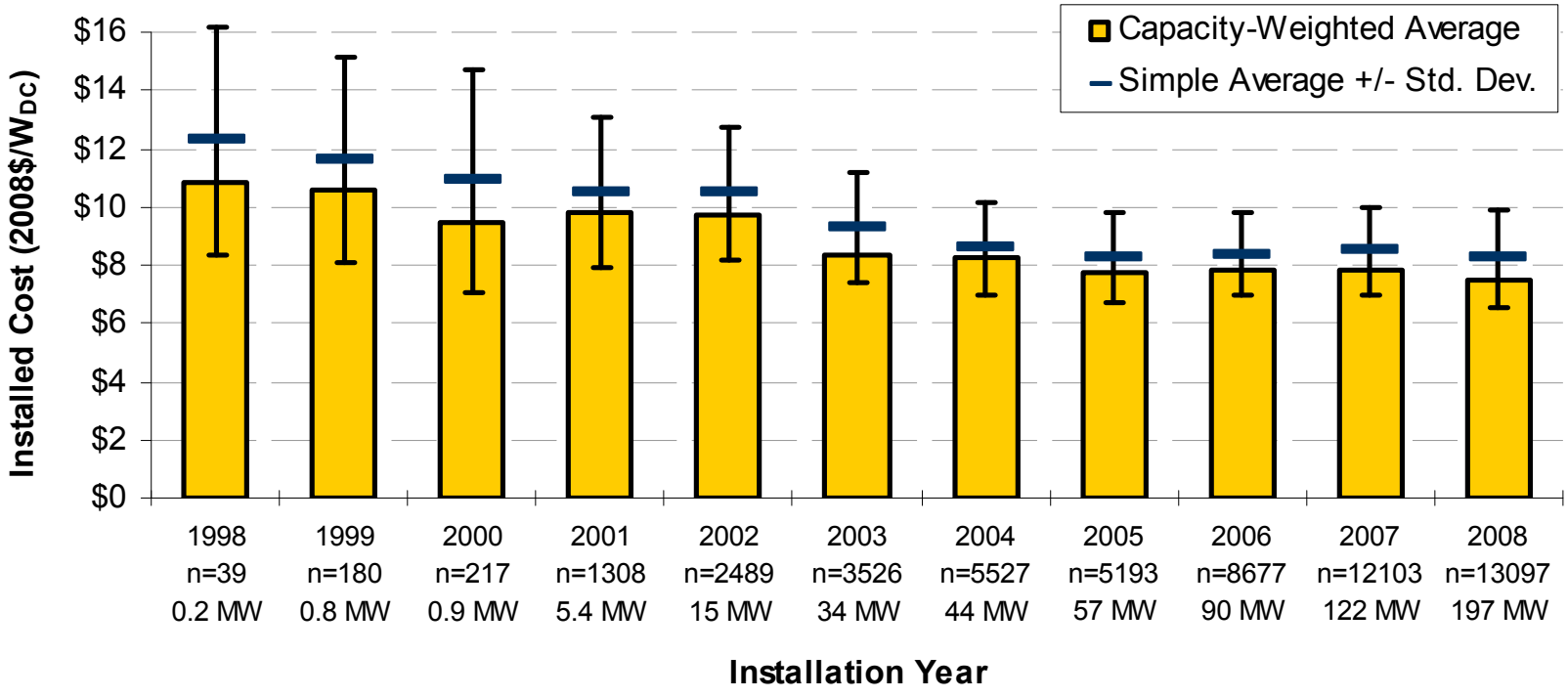
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
No. of Systems	39	180	217	1,308	2,489	3,526	5,527	5,193	8,677	12,103	13,097	***52,356***
% of Total	*<1%*	*<1%*	*<1%*	*2%*	*5%*	*7%*	*11%*	*10%*	*17%*	*23%*	*25%*	***100%***
Capacity (MW$_{DC}$)	0.2	0.8	0.9	5.4	15	34	44	57	90	122	197	***566***
% of Total	*<1%*	*<1%*	*<1%*	*1%*	*3%*	*6%*	*8%*	*10%*	*16%*	*22%*	*35%*	***100%***

PV Installed Cost Trends

(Prior to Receipt of Financial Incentives, Tax Credits, Renewable Energy Certificate Revenues, etc.)

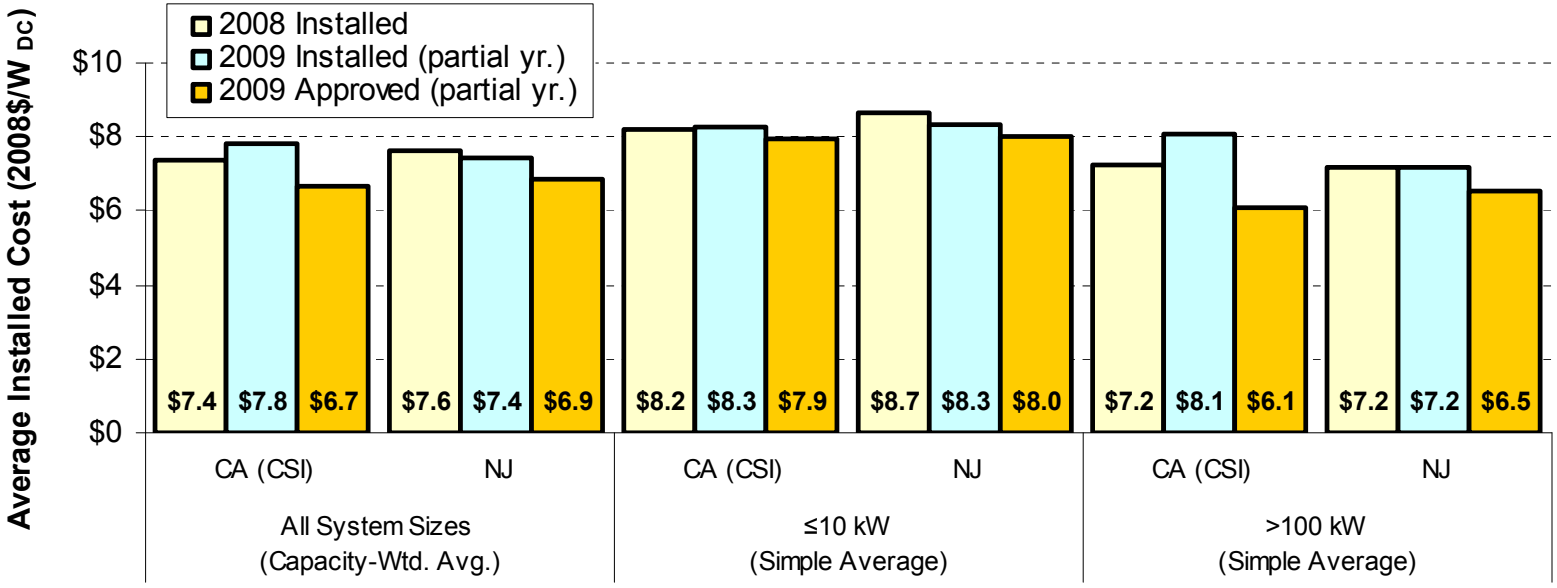
Installed Costs Declined from 2007 to 2008, Following Several Years of Stagnant Costs

Capacity-weighted average costs were **$7.5/$W_{DC}$** in 2008, a **4.6%** reduction from 2007 ($7.8/$W_{DC}$) and a **31%** reduction from 1998 ($10.8/$W_{DC}$).



Preliminary Data Suggest Continued Cost Declines in NJ, but not CA, for 2009

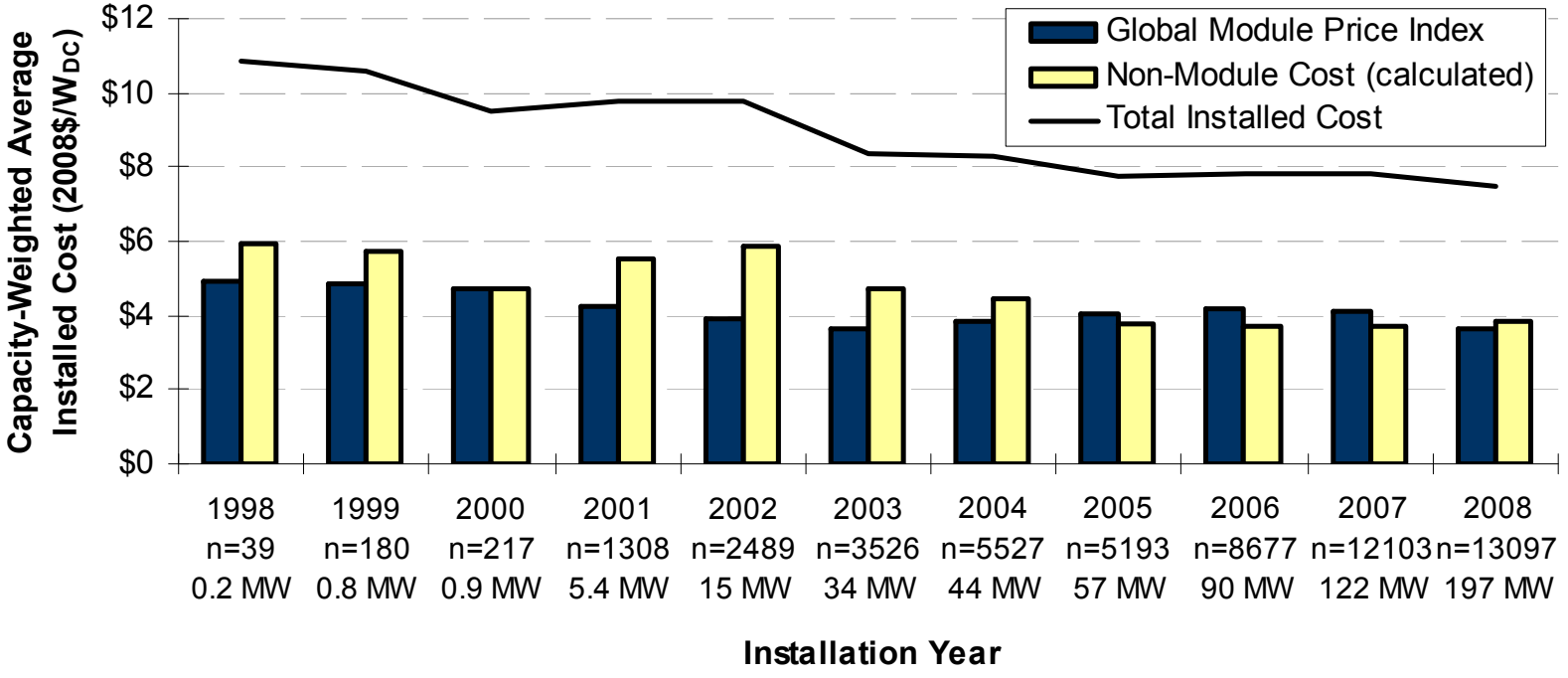
Compared to 2008, the average cost of projects installed within the first 8-8½ months of 2009 has increased within the CA (CSI) program while continuing to fall within NJ's programs



Notes: CA data are from the CSI program (through September 15, 2009), while NJ data are from the CORE Program, SREC-Only Pilot, Renewable Energy Incentive Program, and SREC Registration Program (through August 31, 2009). Cost data for "2009 Installed (partial yr)" are based on systems installed by the aforementioned dates; while data for "2009 Approved (partial yr)" are based on systems with an approved incentive application on file (or that have registered within the NJ SREC program), but that were not yet installed by the aforementioned dates.

The 2007 to 2008 Installed Cost Reduction Is Due Primarily to a Decline in Module Costs

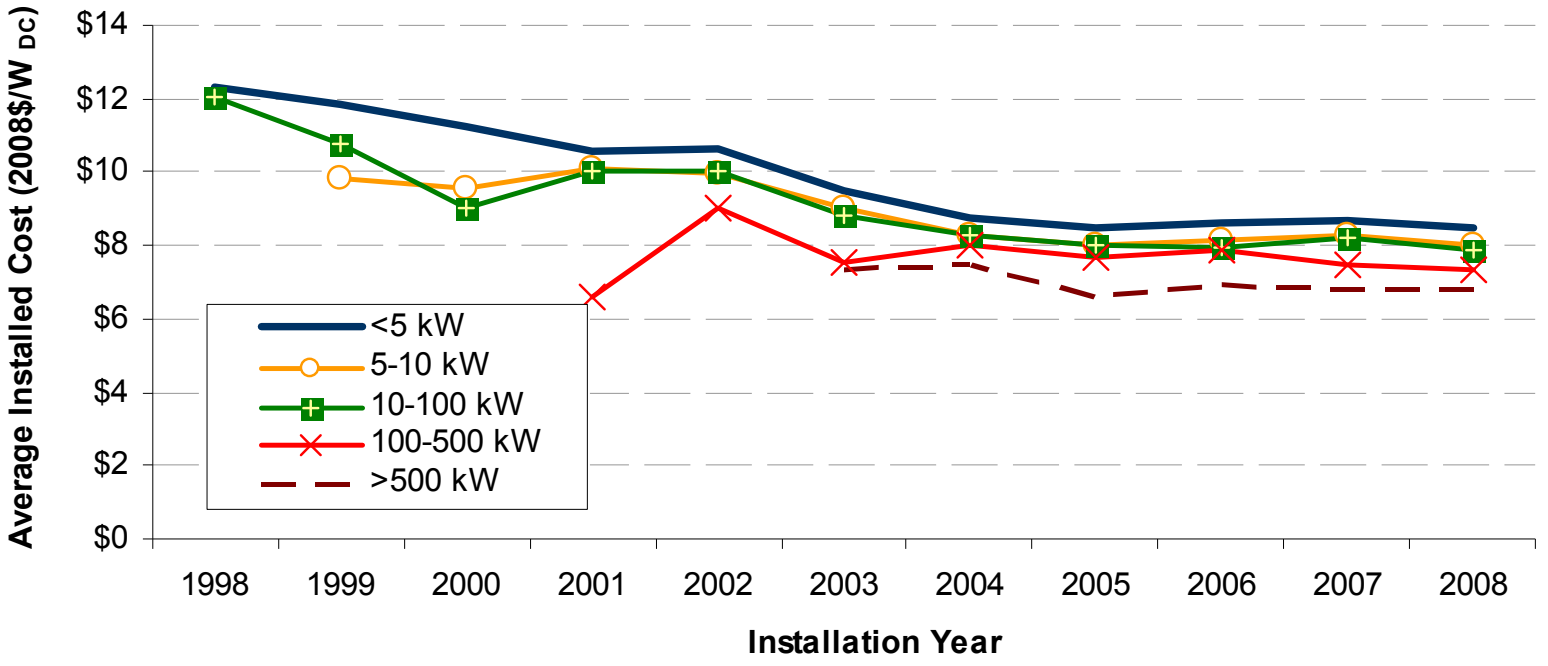
This contrasts with the longer-term trend, in which cost reductions have been primarily associated with a decline in *non-module* costs (which are more readily affected by deployment programs).



Note: Non-module costs are calculated as the reported total installed costs minus the global module price index.

Historical Cost Reductions Are Most Evident Among Smaller Systems

Average annual reduction of **$0.4/W$_{DC}$** from 1998 to 2008, for systems <5 kW$_{DC}$; no significant change in cost of systems >100 kW$_{DC}$ within period of data availability



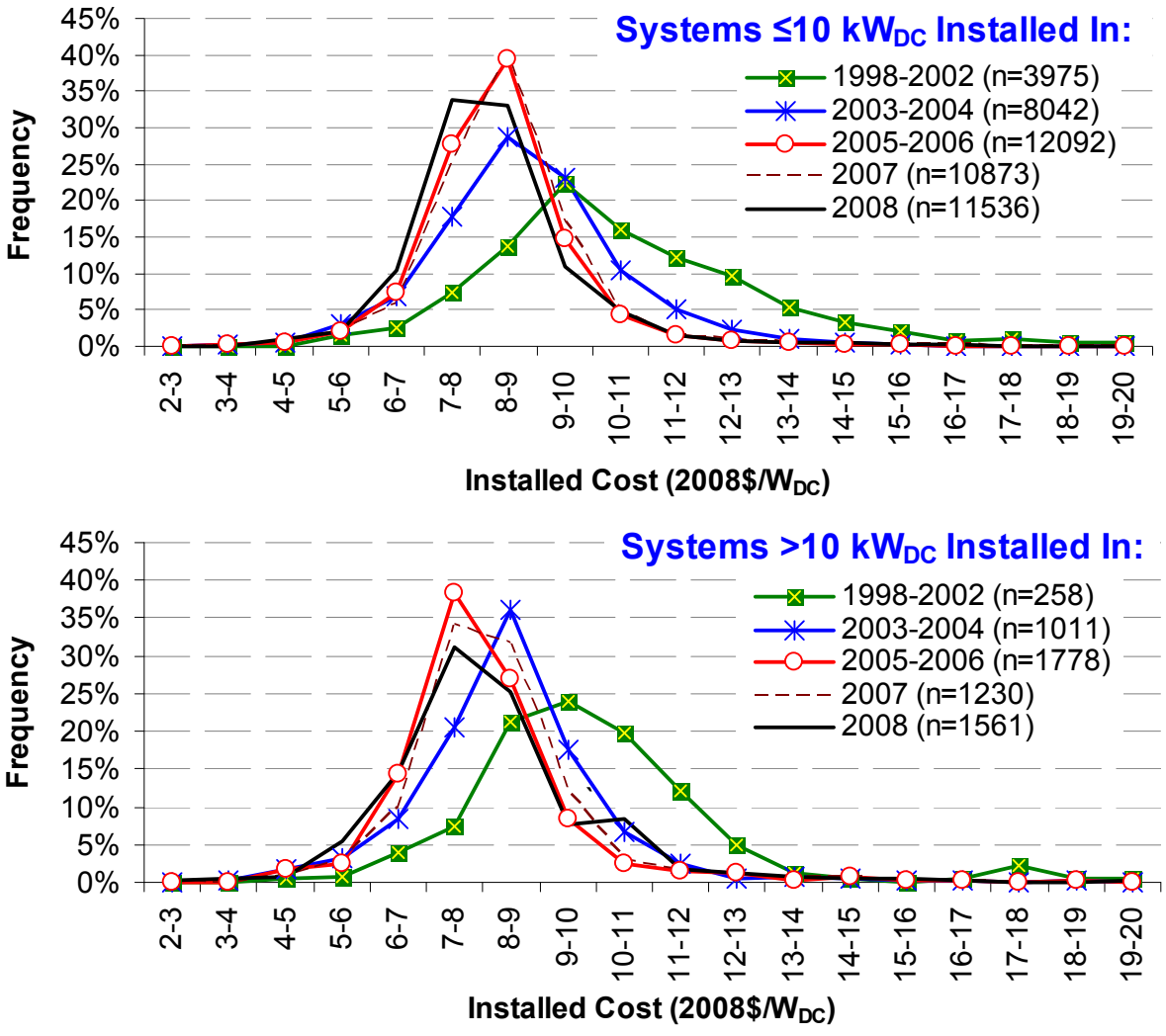
Note: Averages shown only if five or more observations were available for a given size category in a given year.

The Historical Narrowing of the Installed Cost Distribution Ceased from 2006 to 2008

Average Costs Declined from 1998 to 2008 Due To:

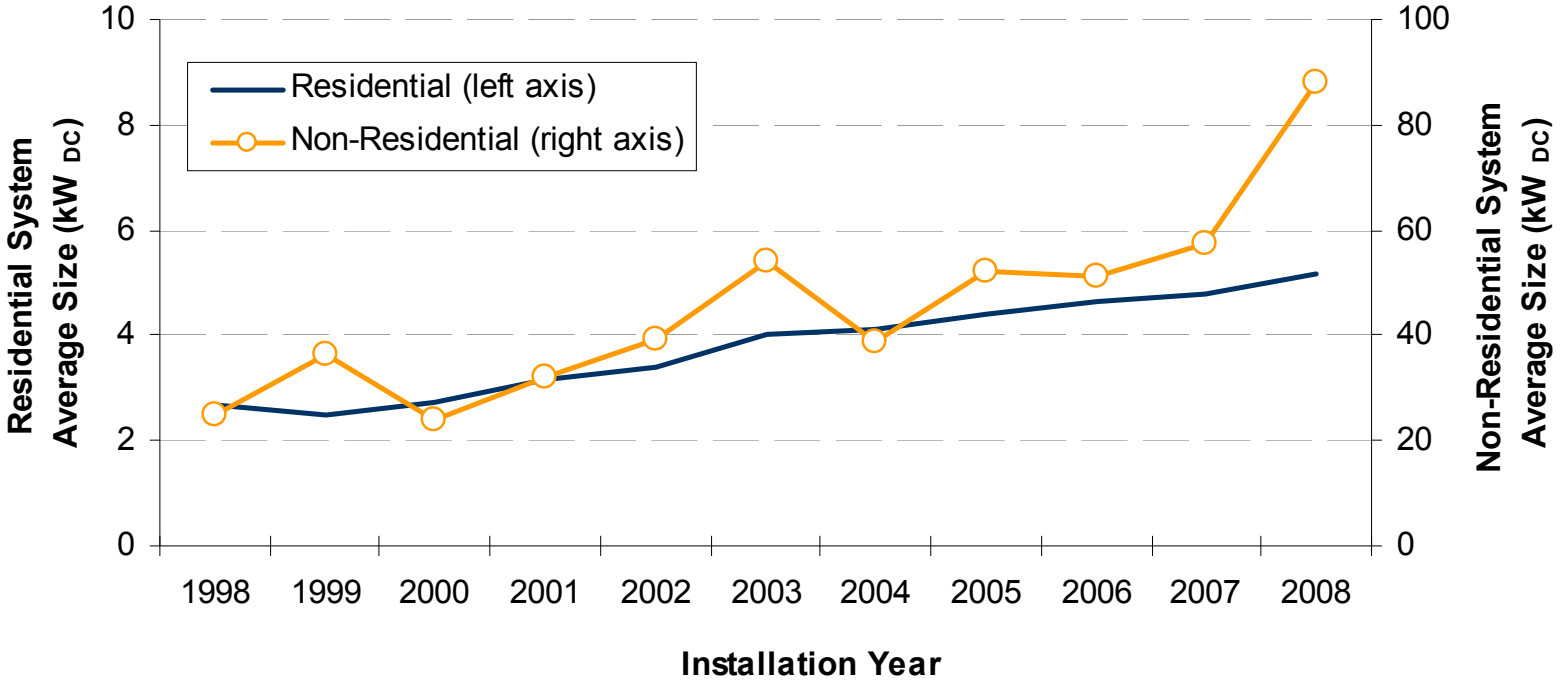
Shifting: Overall shift of the cost distributions toward lower costs

Narrowing: Reduction in high-cost outliers, demonstrating a maturing market in which competition has become more robust



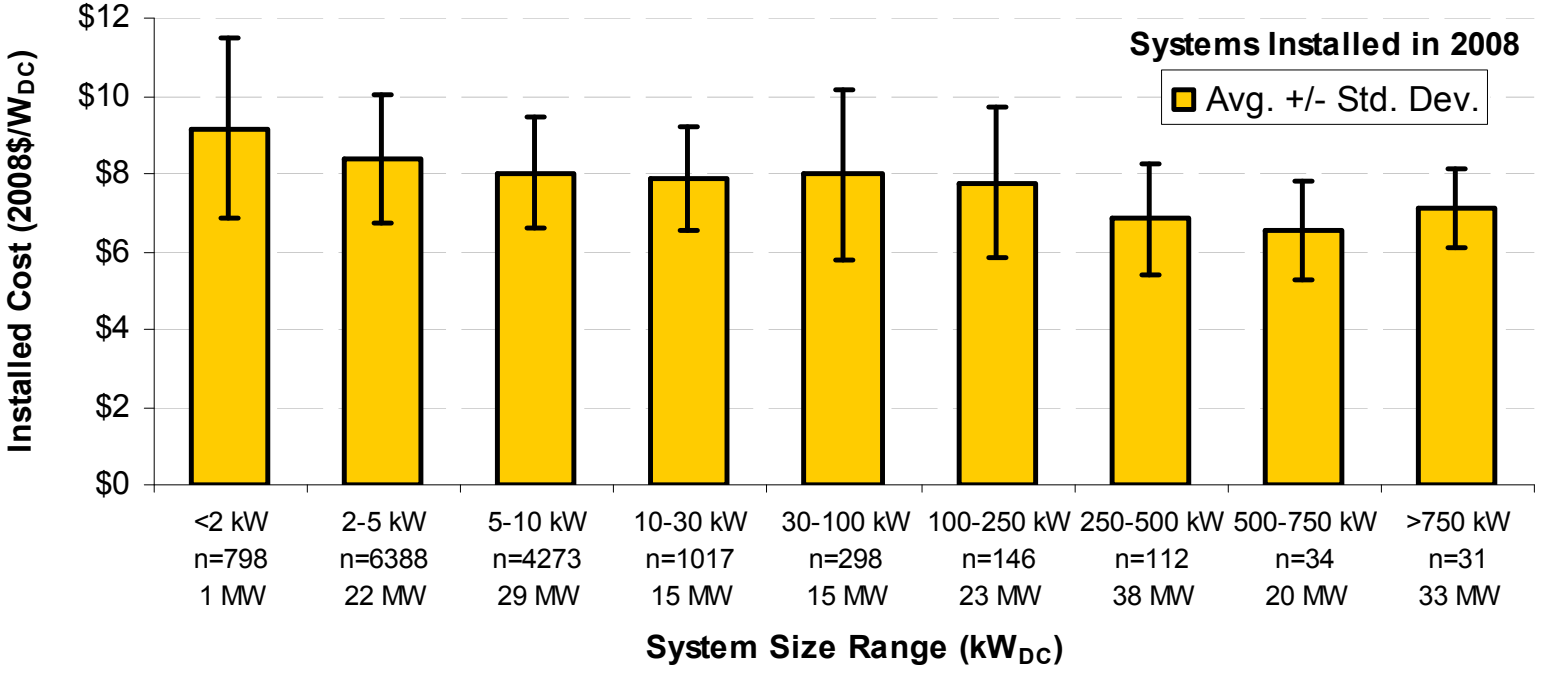
Temporal Cost Reductions Partially Reflect Increasing Average System Size

From 1998 to 2008, the average system size of residential systems almost doubled (from 2.7 kW_{DC} to 5.2 kW_{DC}), while non-residential systems more than tripled in size (from 25 kW_{DC} to 88 kW_{DC}); associated economies of scale reduced cost



Economies of Scale Drive Down Costs as System Size Increases

500-750 kW_{DC} systems are **~30% cheaper**, on average, than <2 kW_{DC} installations; most significant economies of scale occur from 0-5 kW_{DC} and from 100-750 kW_{DC}



Rise in cost for >750 kW systems may be due to greater prevalence of tracking

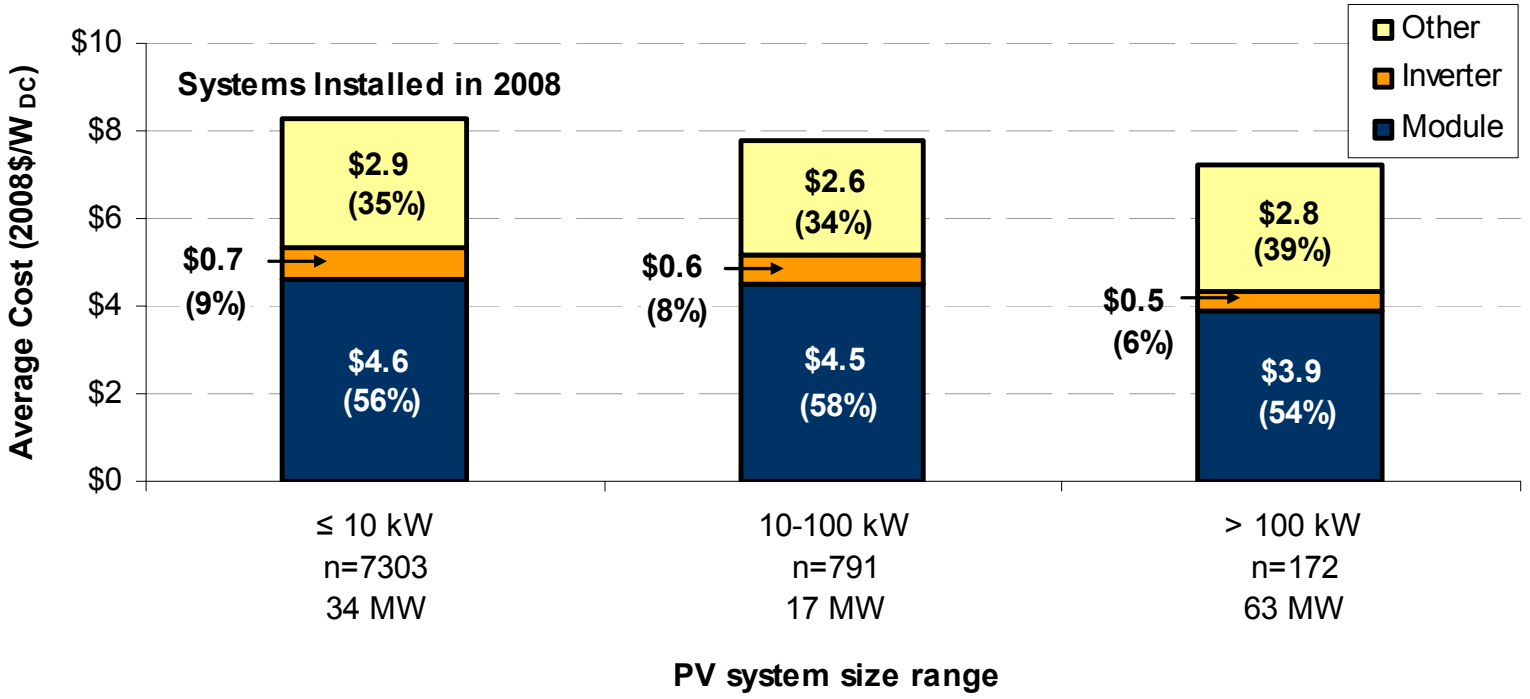
Several Large Projects *Not* in the Primary Sample Have Particularly Low Installed Costs

Location	Year of Installation	Plant Size (kW_{DC})	Installed Cost (2008$/$W_{DC}$)	Actual or Expected Capacity Factor	Tracking System Design
Boulder City, NV	2008	12,600	3.2	21%	none (fixed-axis)
Fairless Hills, PA	2008	3,000	6.7	14%	none (fixed-axis)
Fontana, CA	2008	2,400	4.3	no data	none (fixed-axis)
Riverside, CA	2008	2,000	6.5	15%	none (fixed-axis)
Nellis, NV	2007	14,200	7.3	24%	single axis
Alamosa, CO	2007	8,220	7.6	24%	none, single axis, and double axis
Fort Carson, CO	2007	2,000	6.5	18%	none (fixed-axis)
Springerville, AZ	2001-2004	4,590	6.2	19%	none (fixed-axis)
Prescott Airport, AZ	2002-2006	3,388	5.6	21%	single axis and double axis

Data obtained from assorted public sources (press releases, regulatory filings, etc.)

- Two of the four large projects installed in 2008 (in Boulder City, NV and Fontana, CA) have costs well below the average for >750 kW_{DC} systems in the primary sample ($7.1/$W_{DC}$)
- Several of the projects installed prior to 2008 have tracking systems, and are therefore likely to attain higher performance and a lower levelized cost of electricity (even if the installed cost is higher)

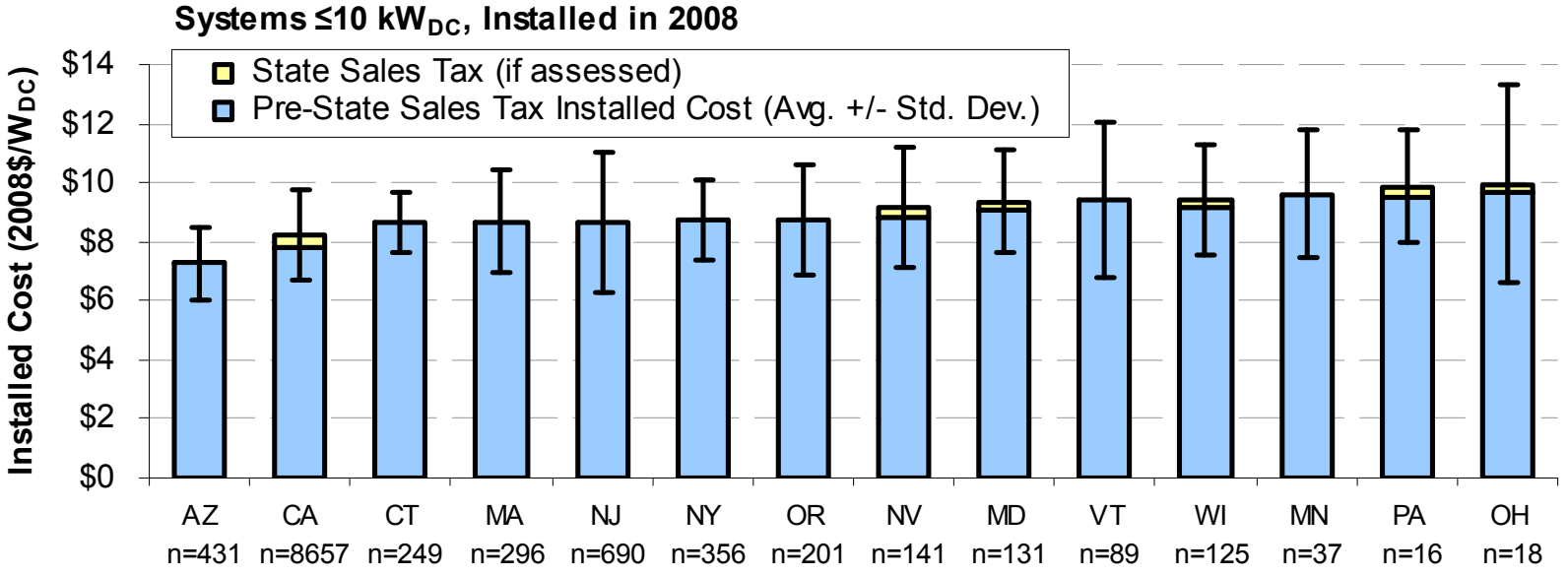
Large Systems Had Significantly Lower Module Costs than Small Systems in 2008



- **Module costs** were \$0.6-\$0.7/W_{DC} lower for systems >100 kW_{DC} than for systems in the two smaller size groupings, indicative of bulk purchasing power for large systems
- **Other** (non-module/non-inverter) costs did not vary appreciably by system size, contrary to conventional wisdom, as many of the costs in the "Other" category (e.g., overhead and transaction costs) would presumably benefit from economies of scale

Installed Costs Vary Widely Across States

California has among the lowest average costs for systems ≤10 kW_{DC}, reinforcing the premise that larger PV markets stimulate greater competition and hence greater efficiency in the delivery chain for PV



A small portion of the cost difference reflects varying sales tax incentives

Notes: State Sales Tax and Pre-State Sales Tax Installed Costs were calculated from 2008 sales tax rates in each state (local sales taxes were not considered). Sales tax was assumed to have been assessed only on hardware costs, which, in turn, were assumed to constitute 65% of the total pre-sales-tax installed cost. CO and WA are excluded from the figure due to insufficient sample size.

Cost Differences Among States Persists Across System Sizes

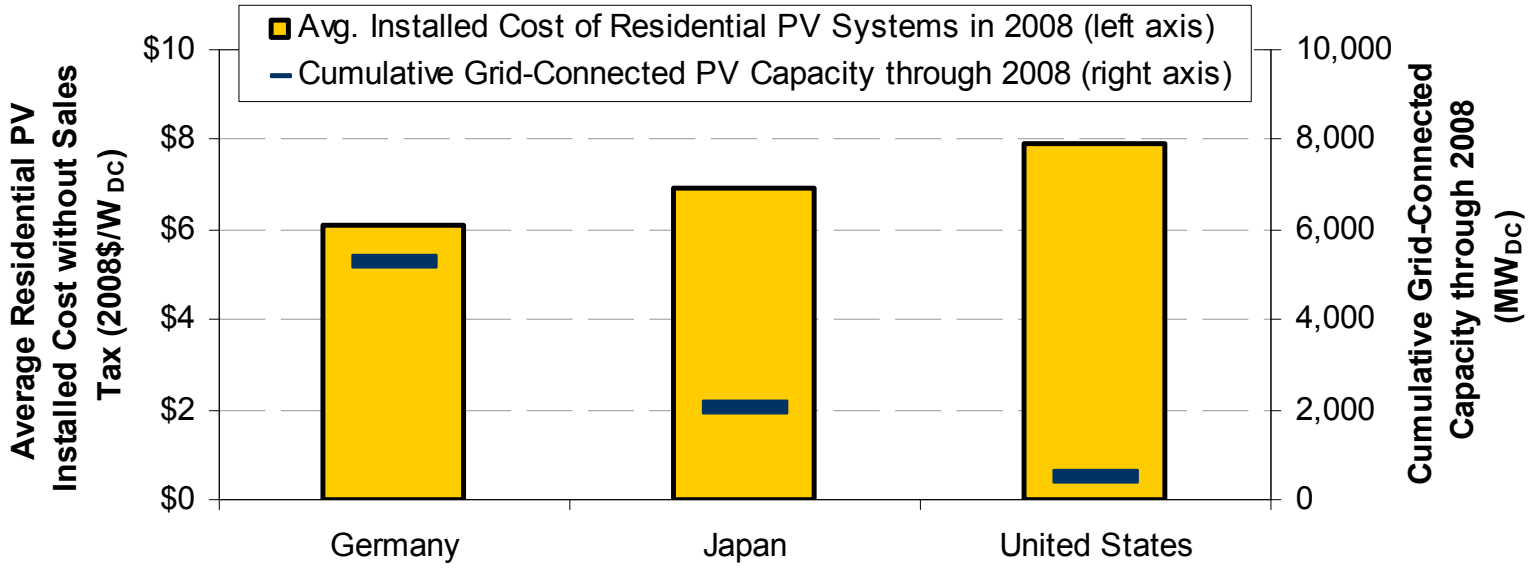
Average Installed Cost ($/$W_{DC}$) by State and PV System Size Range

State	All Reported Yrs. Capacity-Weighted Average Cost (all sizes)		2008 Systems									
			Capacity-Weighted Average Cost (all sizes)		Simple Average Cost							
					0 - 10 kW_{DC}		10 - 100 kW_{DC}		100 - 500 kW_{DC}		>500 kW_{DC}	
AZ	$7.4	(n=1258)	$6.8	(n=477)	$7.3	(n=431)	$6.8	(n=42)	*	(n=4)	*	(n=0)
CA	$7.8	(n=42522)	$7.4	(n=9845)	$8.2	(n=8657)	$7.7	(n=934)	$7.3	(n=199)	$6.8	(n=55)
CO	$8.3	(n=16)	$8.3	(n=16)	$8.3	(n=16)	*	(n=0)	*	(n=0)	*	(n=0)
CT	$8.1	(n=623)	$7.9	(n=310)	$8.6	(n=249)	$8.3	(n=49)	$7.6	(n=12)	*	(n=0)
MA	$9.1	(n=1091)	$8.0	(n=336)	$8.7	(n=296)	$8.7	(n=34)	$7.4	(n=6)	*	(n=0)
MD	$9.4	(n=230)	$9.0	(n=135)	$9.3	(n=131)	*	(n=4)	*	(n=0)	*	(n=0)
MN	$8.9	(n=145)	$9.8	(n=38)	$9.6	(n=37)	*	(n=1)	*	(n=0)	*	(n=0)
NJ	$7.9	(n=3225)	$7.6	(n=860)	$8.7	(n=690)	$8.3	(n=132)	$7.2	(n=29)	$6.9	(n=9)
NV	$9.1	(n=393)	$8.8	(n=145)	$9.2	(n=141)	*	(n=4)	*	(n=0)	*	(n=0)
NY	$8.9	(n=1158)	$8.6	(n=401)	$8.7	(n=356)	$8.8	(n=45)	*	(n=0)	*	(n=0)
OH	$9.6	(n=35)	$9.5	(n=23)	$9.9	(n=18)	*	(n=4)	*	(n=1)	*	(n=0)
OR	$8.3	(n=878)	$8.4	(n=248)	$8.7	(n=201)	$9.4	(n=39)	$8.2	(n=7)	*	(n=1)
PA	$9.3	(n=164)	$9.5	(n=18)	$9.9	(n=16)	*	(n=2)	*	(n=0)	*	(n=0)
VT	$8.7	(n=225)	$9.1	(n=94)	$9.4	(n=89)	$8.8	(n=5)	*	(n=0)	*	(n=0)
WA	$7.7	(n=7)	$7.7	(n=6)	$8.9	(n=6)	*	(n=0)	*	(n=0)	*	(n=0)
WI	$8.9	(n=386)	$9.0	(n=145)	$9.4	(n=125)	$8.6	(n=20)	*	(n=0)	*	(n=0)

* Cost data is omitted if the sample size (n) is less than five.

Avg. Cost of Small Residential PV In the U.S. Exceeds that in Germany and Japan

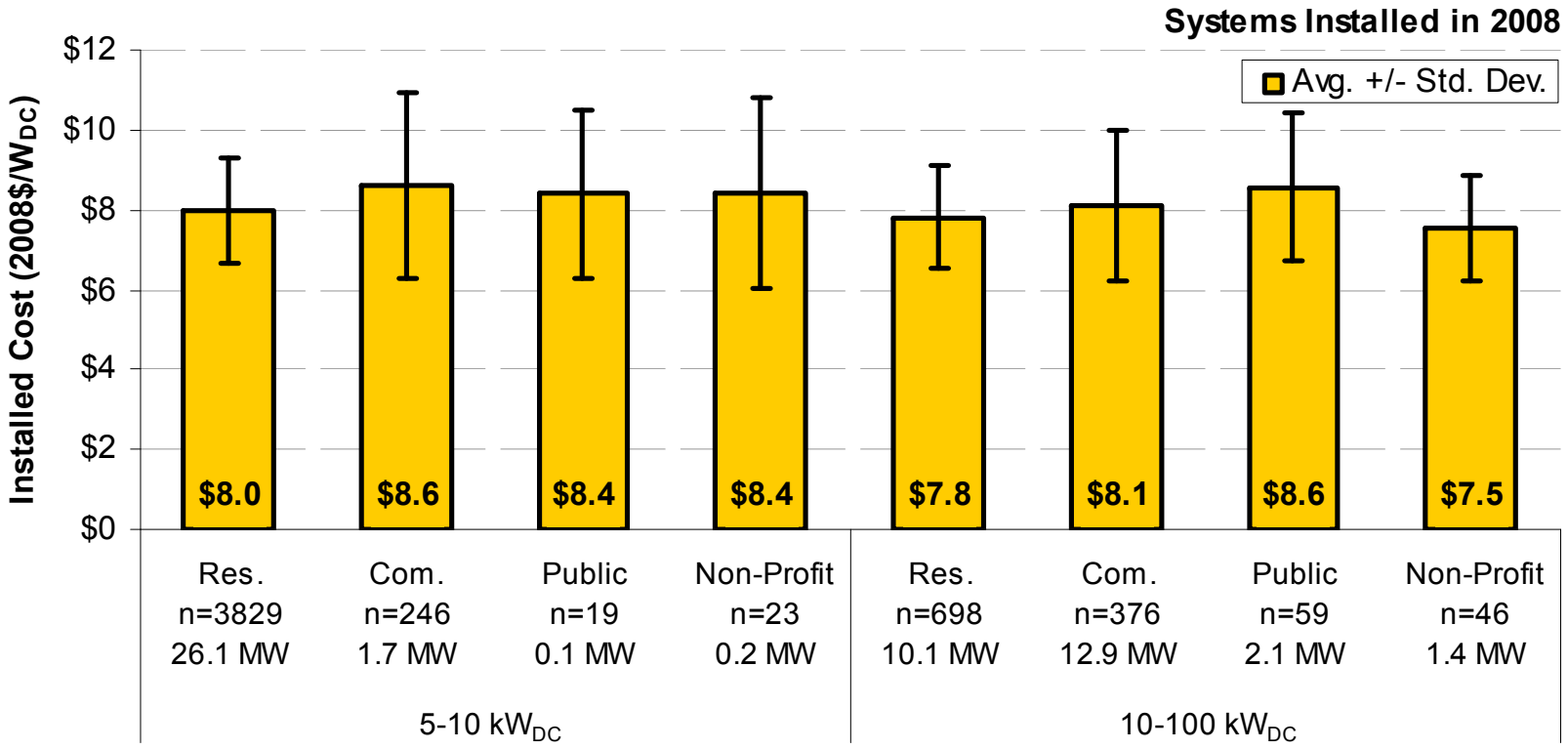
Figure presents average cost of small residential systems installed in 2008 (excluding sales tax and VAT), and cumulative grid-connected PV capacity



Note: The Japanese and U.S. cost data are for 2-5 kW_{DC} systems, while the German cost data are for 3-5 kW_{DC} systems.

- Lower costs in Germany and Japan suggest that further near-term cost reductions in the U.S. may be possible
- Lower costs may be partly attributable to greater deployment scale, but other factors also likely play an important role

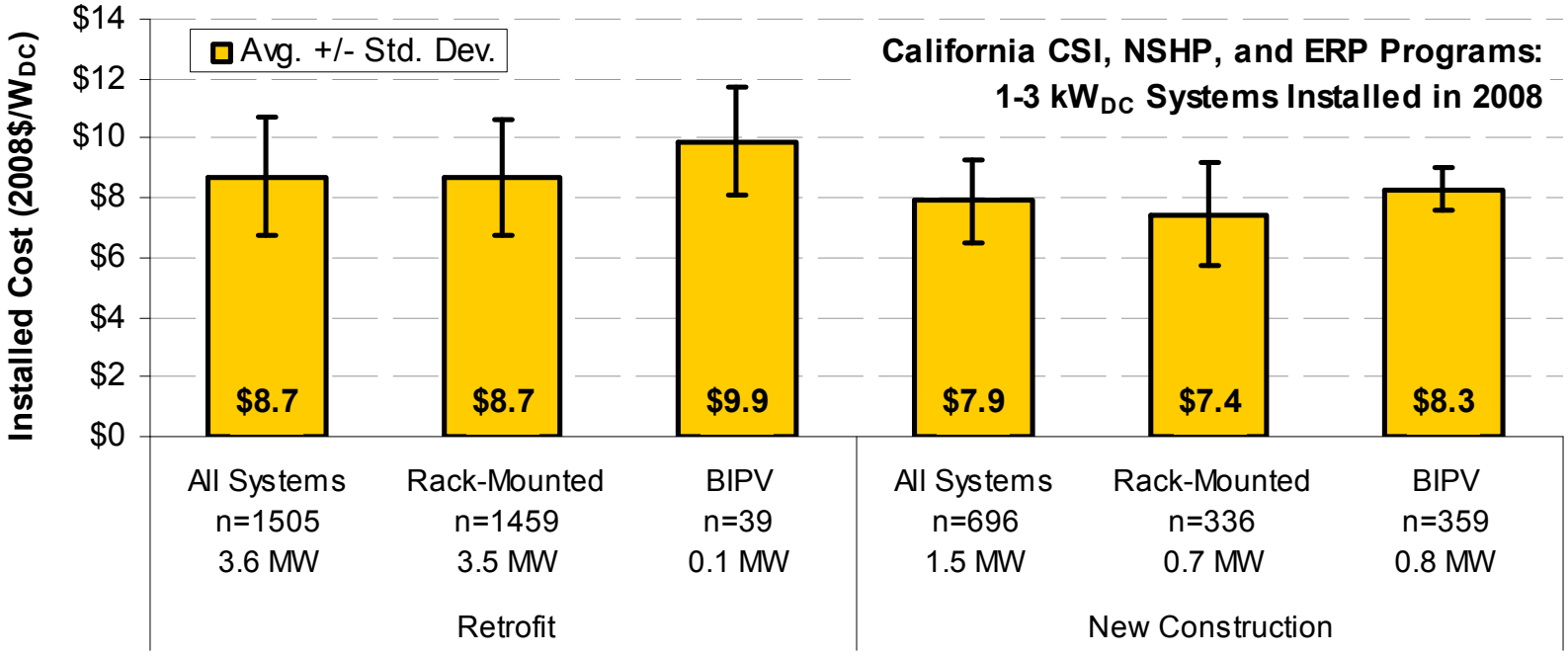
Resid. PV Has Lower Costs than Similarly Sized Commercial & Public-Sector Systems



- Among 5-10 kW_{DC} systems installed in 2008, residential PV had an average installed cost \$0.6/W_{DC} less than commercial and \$0.4/W_{DC} less than public sector
- Within the 10-100 kW_{DC} size range, residential PV had average costs \$0.3/W_{DC} below commercial and \$0.8/W_{DC} below public sector

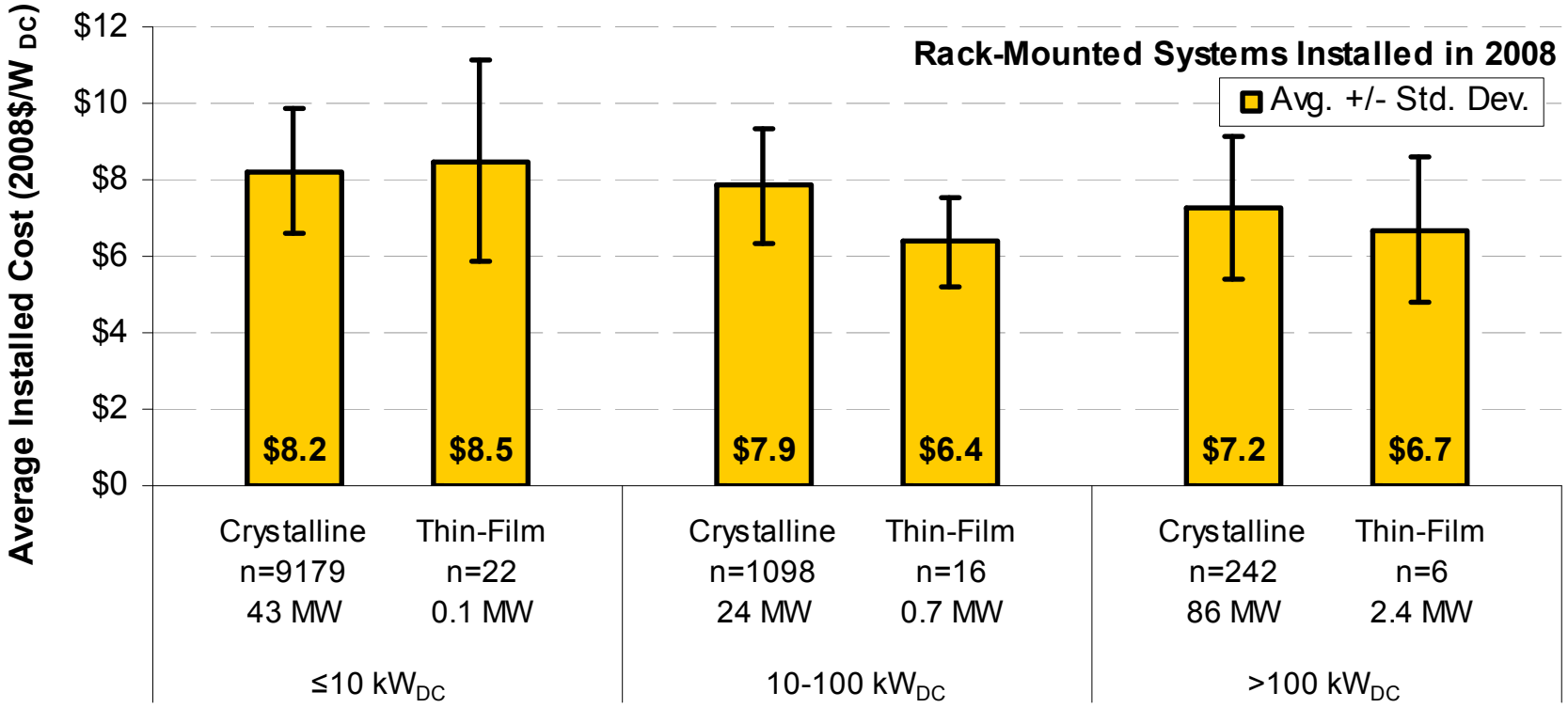
The New Construction Market Offers Cost Advantages for Residential PV

In 2008, residential new construction systems cost **$0.8/$W_{DC}$** less, on average, than similarly sized retrofit systems (**$1.3/$W_{DC}$** less if only rack-mounted systems are compared)



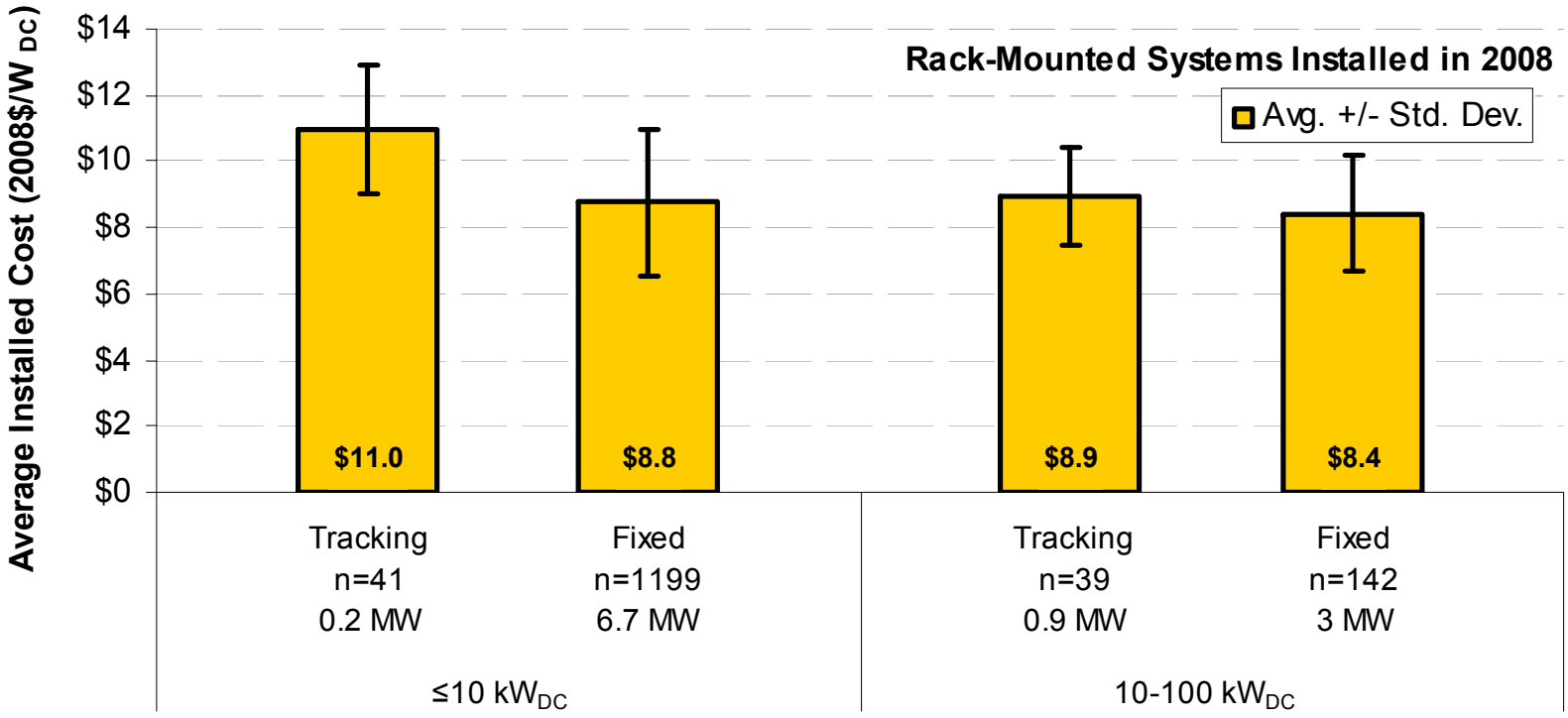
Note : The number of rack-mounted systems plus BIPV systems may not sum to the total number of systems, as some systems could not be identified as either rack-mounted or BIPV.

Medium & Large Thin-Film Systems Have Lower Installed Costs than Crystalline



- Thin-film systems in both the 10-100 kW_{DC} and >100 kW_{DC} size ranges have average costs substantially lower than comparably-sized crystalline systems
- Small sample sizes for thin-film systems warrant caution in drawing definitive conclusions about the significance of the cost differential

Systems with Tracking Have Moderately Higher Costs than Fixed-Axis Systems



- Although the sample size is small, 10-100 kW tracking systems installed in 2008 had average installed costs $\$0.5/W_{DC}$ (or 6%) greater than fixed-axis systems
- The cost differential was considerably greater for systems ≤10 kW_{DC} (though tracking equipment is generally not considered for systems in this size range)

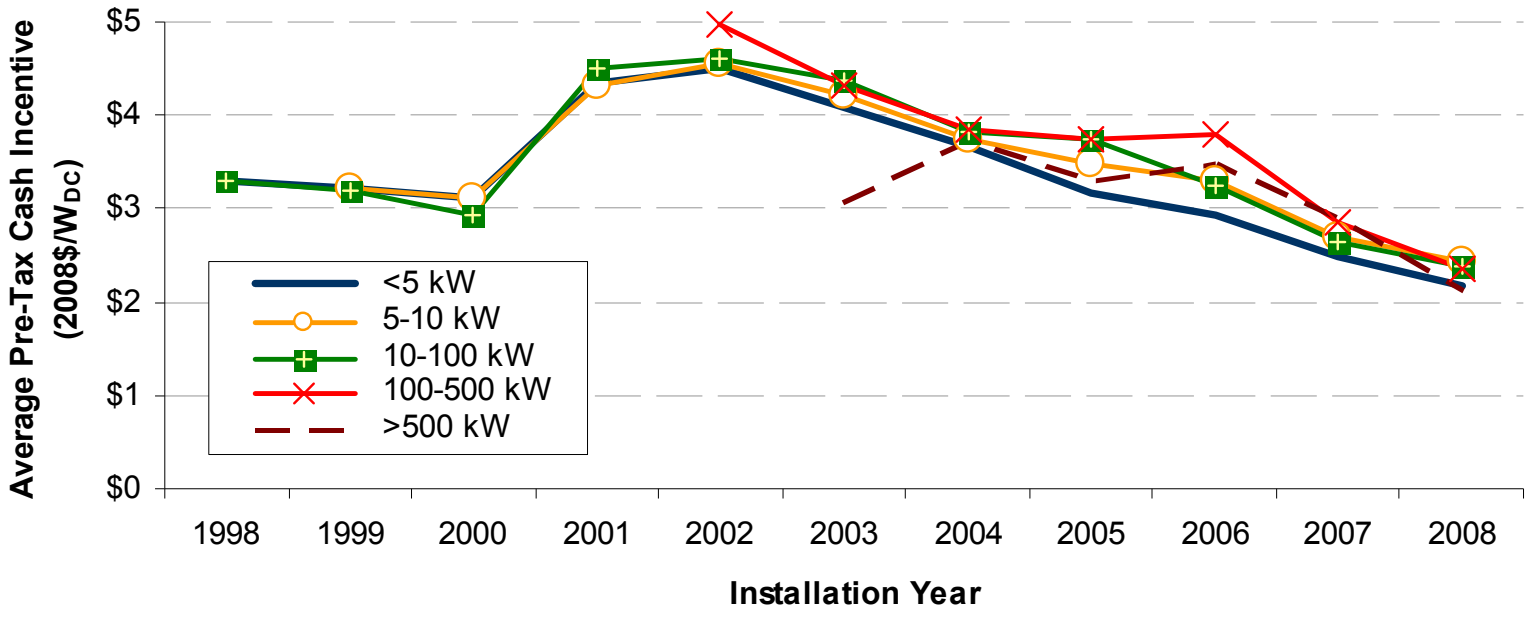
PV Incentive and Net Installed Cost Trends

Key Assumptions Used to Derive Incentive Trends and Net Installed Costs

- Incentives and net installed costs (i.e., customer cost after receipt of incentives) are calculated and account for:
  - Cash incentives provided by the PV incentive programs in the data sample
  - State and Federal investment tax credits (ITCs)
- But do not account for:
  - Cash incentives potentially provided by other PV incentive programs
  - Revenue from renewable energy certificates (RECs)
  - The value of accelerated depreciation (applicable to commercial PV only)
- NJ SREC-Only Pilot Program is excluded (as the incentive is provided solely in the form of uncertain future REC payments)
- 10 kW was used to delineate between residential and commercial PV if no other information was available on customer type

State/Utility Cash Incentives Have Declined since 2002

Figure shows the average **cash incentive** on a pre-tax basis



Note: Averages shown only if five or more observations were available for a given size category in a given year.

- Average pre-tax cash incentives received by projects installed in 2008 ranged from $\$2.1/W_{DC}$ - $\$2.4/W_{DC}$ across the system size ranges shown, down by 50% from their peak in 2002
- Trends largely reflect incentive levels under CA and NJ programs

REC Revenues Add to Overall Incentives, But Impact Varies Widely

In general, the revenue potential from the sale of RECs depends on where the system is located and what REC markets are available:

1. **Voluntary REC Markets**: prices averaged about $4/MWh in 2008, which, extrapolated over a 20-year period, are equivalent to **$0.05/$W_{DC}$** on a pre-tax present-value basis
2. **Traditional RPS Markets** (no solar set-aside): the highest prices in 2008 occurred in Massachusetts, where Class I RECs averaged $45/MWh, equivalent to **$0.52/W_{DC}** (if extrapolated over a 20-year period)
3. **RPS Solar Set-Aside Markets**: Solar REC prices in New Jersey averaged $390/MWh in 2008, equivalent to **$4.0/$W_{DC}$** (if extrapolated over a 15-year period)

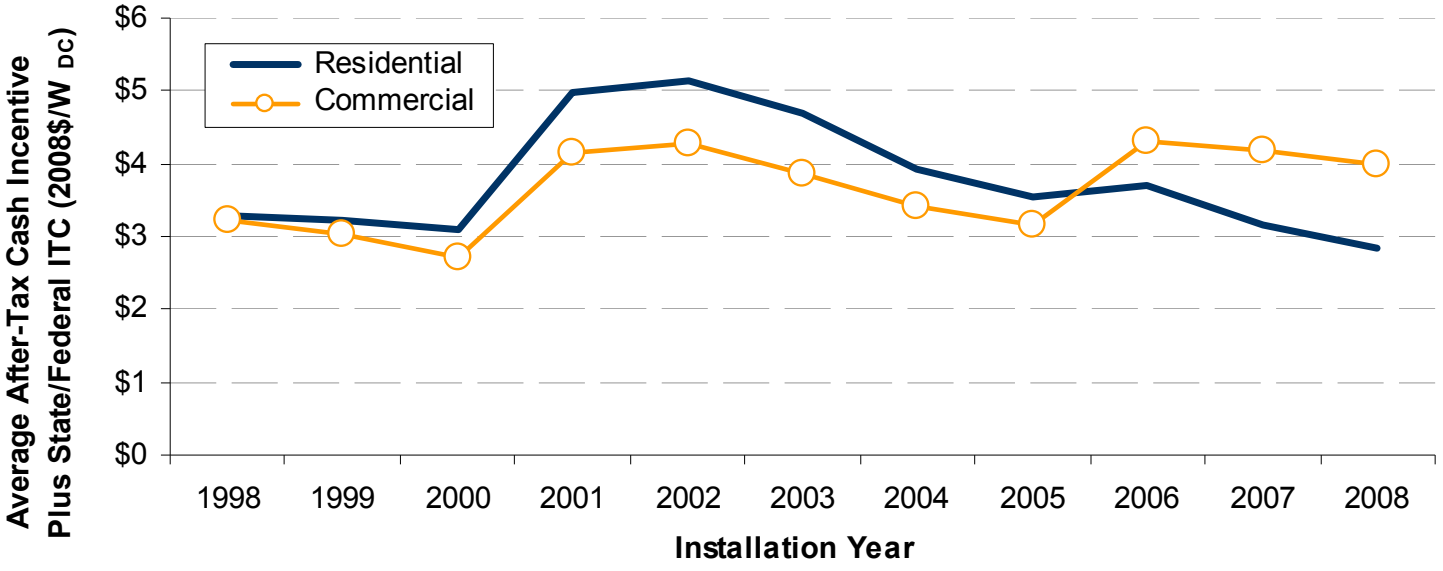
** Source of historical REC price data: Spectron*

*** $/$W_{DC}$ estimates calculated assuming 10% nominal discount rate and 14% capacity factor*

Because the present-value of REC revenue is uncertain and variable, it is **not** included in the slides that follow

Including Federal & State ITCs, Incentives Were at a Near-All-Time High for Commercial PV in 2008 but at an Historic Low for Residential PV

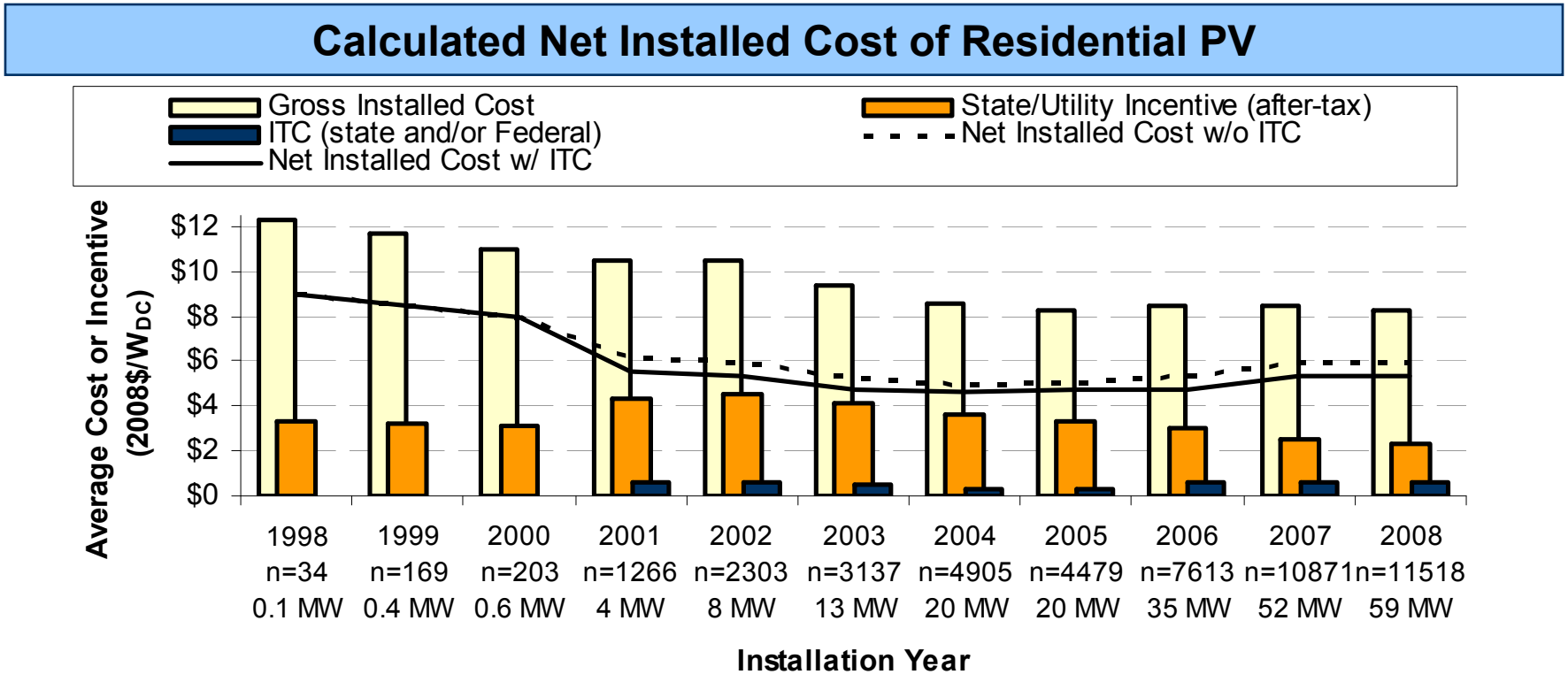
Figure shows the combined value, on an after-tax basis, of direct **cash incentives** plus **state/Federal ITCs** (excludes RECs and accelerated depreciation)



Shift towards commercial PV installations partially explained by these trends

- Increase in Federal ITC in 2006 for commercial PV provided a significant boost; consequently, incentives for commercial PV were at a near-high in 2008
- Residential PV will see a similar benefit starting in 2009, as a result of the lifting of the $2,000 cap on the Federal ITC for residential PV

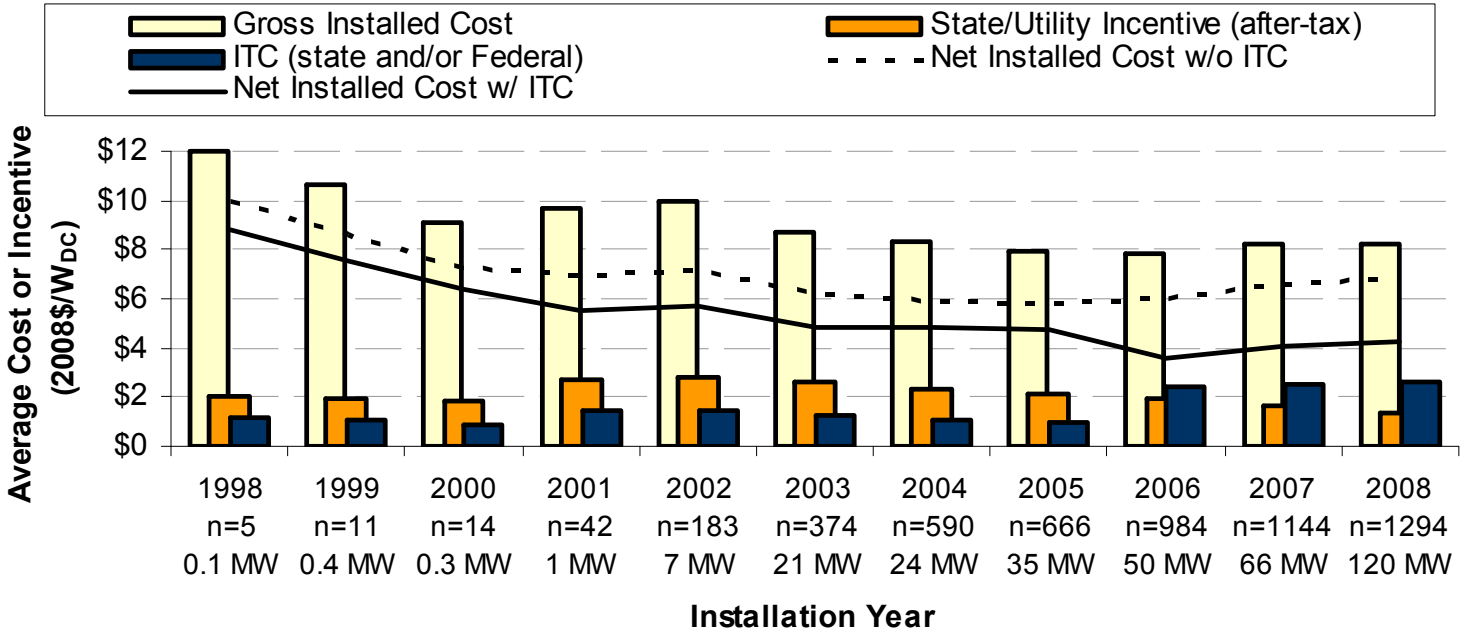
The Net Installed Cost of Residential PV Rose Slightly from 2007 to 2008



- The net installed cost of residential PV was \$5.4/W_{DC} in 2008, up approx. 1% from 2007 and 15% (\$0.7/W_{DC}) from its all-time low in 2004 (\$4.7/W_{DC}).
- Net installed costs rose from 2004 to 2008, as declining incentives outpaced cost reductions

…While Rising Slightly More for Commercial PV

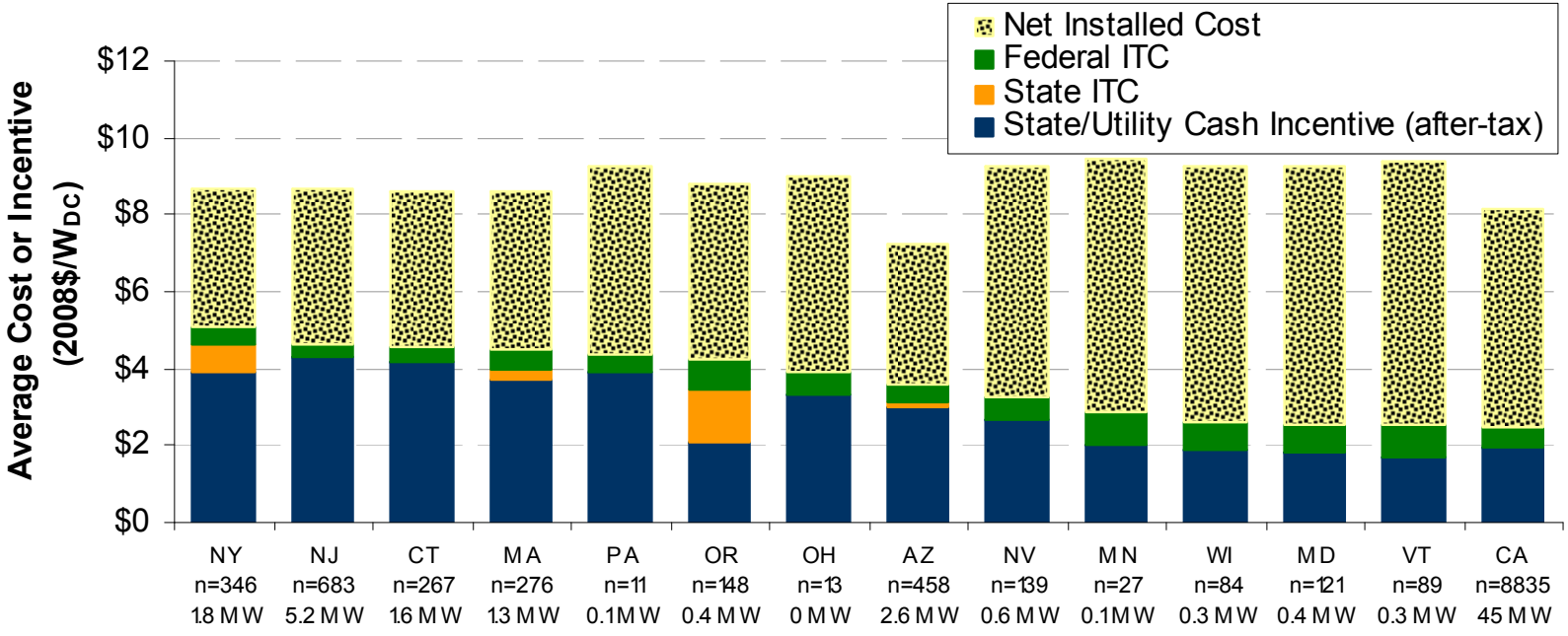
Calculated Net Installed Cost of Commercial PV



- The net installed cost of commercial PV was \$4.2/W_{DC} in 2008, up 5% from 2007 and up 18% from its all-time low in 2006 (\$3.9/W_{DC})
- Net installed costs remain significantly lower for commercial PV than for residential, due primarily to the more lucrative Federal ITC prior to 2009
- Potential impact of incentive levels on gross installed costs illustrated by trends from 2000-02, when gross costs rose with average incentive levels

Incentives Have Diverged Widely Across States for Residential Systems...

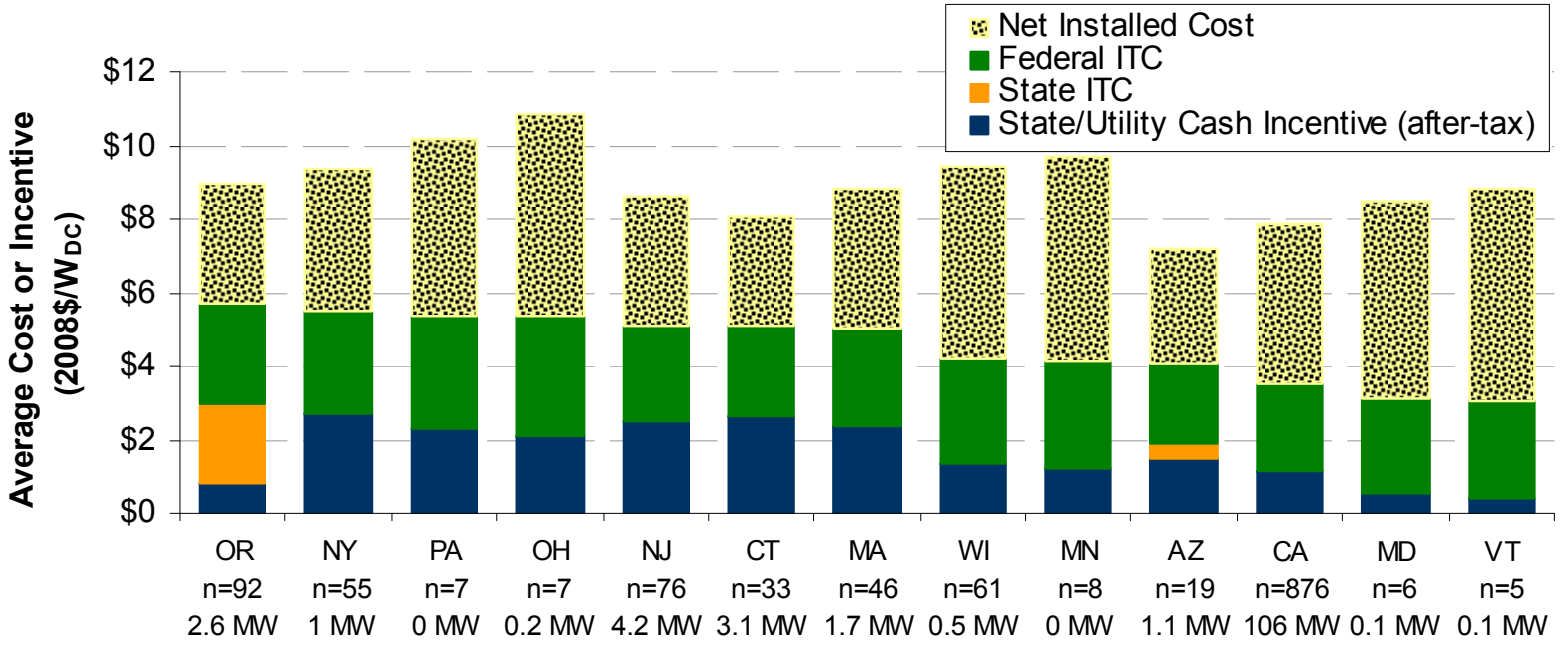
After-Tax Incentives and Net Installed Cost of Residential PV Systems Installed in 2008



- Average combined after-tax incentive (cash incentives plus ITCs) for residential PV ranged from \$2.5/W_{DC} in California to \$5.1/W_{DC} in New York in 2008
- The two largest markets - California and New Jersey - differed substantially in terms of average financial incentives for residential PV installed in 2008

...And Also for Commercial Systems

After-Tax Incentives and Net Installed Cost of Commercial PV Systems Installed in 2008



- Average combined after-tax incentives (cash incentives plus ITCs) ranged from \$3.1/W_{DC} in Vermont to \$5.7/W_{DC} in Oregon
- Net installed costs ranged from a low of \$3.0/W_{DC} in CT (though NJ would likely be lowest if SRECs were included) to a high of \$5.8/W_{DC} in VT

Conclusions and Outlook

Conclusions

- Costs resumed their decline in 2008, following several years of stagnation
  - Reports of dramatic declines in wholesale module costs in 2009 suggest that steep reductions in installed costs are likely in the near-term, although this is only weakly supported by preliminary installed cost data for 2009
  - Lifting of the cap on the Federal ITC for residential PV, also beginning in 2009, will reduce net installed costs for residential customers
- Since 1998, PV costs have declined substantially, especially among smaller systems, and primarily as a result of reductions in non-module costs (though very recent cost reductions have been driven largely by a decline in module costs)
- This trend, along with the narrowing of cost distributions, suggests that PV deployment policies in the U.S. have achieved some success in fostering competition and spurring efficiencies in the delivery infrastructure
- Lower average costs in Japan and Germany (and among some of the larger PV markets in the US) suggest that deeper near-term installed cost reductions are possible and may accompany deployment scale

For More Information...

Download the full report, when complete, from:

http://eetd.lbl.gov/ea/ems/re-pubs.html

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